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ENERGY EFFICIENCY IN THE ACI (ASEAN-CHINA-INDIA) COUNTRIES: IS THERE ROOM FOR REGIONAL POLICY COORDINATION?

PARTHA GANGOPADHYAY*
Western Sydney University, NSW,
Australia & University of the South Pacific, Fiji.

SRIRAM SHANKAR
Australian National University,
Canberra, Australia.

Energy efficiency and conservation are the major tools in the reduction of environmental impact and ecological footprints of the energy sector, particularly with regard to climate change. Energy efficiency also contributes to reducing external dependence and vulnerabilities of nations to shocks in the energy markets. At the global level, for arresting the global environmental degradation and costs of climate change, energy efficiency is of utmost importance for the emerging economies of Asia since the centre of gravity of the global economy has been continually tilting towards the Northern Indian Ocean close to the geographic proximity of ASEAN-China-India known as ACI nations. With a combined population of 3.15 billion and intraregional annual trade amounting to $1 trillion, the ACI nations are and will remain a major user of energy. These (ACI) nations will be an important piece in the jigsaw puzzle of the sustainability of the global economy, as these nations can pose a serious risk for creating and exaggerating the vulnerabilities of the global economy to climate shocks. In this paper we develop a quantitative technique, for the very first time to the best of our understanding, to examine the impacts of macroeconomic factors on energy efficiency and apply the method to understand the determinants of energy efficiency in the regional economy of the ACI nations. The cross-country dataset is constructed on the basis of secondary data on energy uses and several macroeconomic variables for China, India and nine (9) ASEAN countries over the period of 1989–2010. From the empirical findings we highlight the most appropriate policies for improving energy efficiency in the region that will be the home of one half of the global population by 2030. Although not all public policies seem effective, yet we are able to home in on a specific mix of policies and their coordination for promoting energy efficiency for and sustainability of the ACI nations.

JEL classification codes: C23, D12, Q41

Keywords: Energy efficiency, stochastic frontier analysis, interest-group politics, reputational dynamics, mixed-strategy equilibrium.

*Corresponding Author, Email: p.gangopadhyay@westernsydney.edu.au or Gangopadhyay_p@usp.ac.fj

1. Introduction

Energy security has assumed critical importance in the face of rapid growth in the emerging countries of Asia—ASEAN, People's Republic of China (PRC) and India. We call them the AIC countries in this work. High rates of economic growth, industrialisation, and increased consumption as a result of improved lifestyles among ACI countries are the major drivers of the continual increase in consumption of energy resources and reliance on energy imports in the region. As a quick stock-stake of economic facts one may note that from 1987 to 2007, primary energy consumption increased by 239%, 214% and 196% in ASEAN, PRC and India, respectively. In terms of the contributed average annual growth, they experienced about 6% annual growth in the absorption of energy (6.3%, 6.1% and 5.6% respectively for ASEAN, PRC and India). Moreover, PRC, India and ASEAN made up 16.09%, 3.95% and 3.45% of world primary energy consumption in 2007[1]. In other words, energy security is and will be a major issue for the ACI countries. On the supply side of energy, the region also plays a significant role: the region is rich in both exhaustible and renewable energy sources. In 2008PRC contributed 40% to world's coal production. In simple terms PRC is the largest producer of coal in the world economy. Interestingly, India is at 2nd place but its contribution in world production is small compared to PRC at 7.8% while ASEAN produces 5.3% of coal at the 3rdplace in the global coal market[2].In terms of oil consumption only, PRC was the world's second largest consumer of petroleum while India was the fourth in 2009[3]. Despite a large and growing consumption of energy resources at present, it is still expected that the demand for energy will increase along with economic growth in the region. Given the limited stocks of fossil fuels in the region, energy efficiency is a pressing issue for ACI countries that needs to be addressed. Among the ACI, India has the largest energy intensity[4]. Although the figure is decreasing, it is still more than twice the value of OECD countries.[5]

ACI produces energy from local resources such as oil and natural gas and it also uses renewable energy like geothermal, hydro and wind energy. However, these sources are not enough, making ACI countries heavily dependent on imported energy resources to satisfy their energy appetite. This heavy dependence of the ACI economies on imported energy calls forth a careful regional planning of energy resources for maintaining the region's spectacular performance in terms of economic growth.

In order to achieve energy security, both PRC and India are making efforts to secure their energy needs through outward investments in energy, financial support to energy producing firms and energy diplomacy.[6] Meanwhile, the ASEAN created cooperation in energy production and consumption among member states through the ASEAN Power

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[1]International Energy Statistics. US Energy Information Administration. http://tonto.eia.doe.gov

[2]International Energy Statistics. Op cit.

[3]International Energy Statistics. Ibid.

[4]Total Primary Energy per GDP

[5]India Energy Portal. "Indian energy sector: an overview" http://www.indiaenergyportal.org/overview_detail.php

[6]Zhao, Hong. "China and India: The Energy Policies." EAI Background Brief No. 462. East Asian Institute. National University of Singapore. (2009). Available: http://www.eai.nus.edu.sg/BB462.pdf

Grid and the Trans-ASEAN Gas Pipeline to achieve more efficient distribution of energy resources in the region. These efforts can be taken further by integrating the efforts of PRC, India and ASEAN in securing renewable energy resources in the context of reducing dependence on fossil fuel and pursuing environmental sustainability. As the magnitude and growth of consumption continue to increase in the face of scarce supply, an analysis of alternative demand and production scenarios with emphasis on Green House Gas (GHG) implications and low-carbon strategies, costs of alternative adjustment strategies as well as policies to arrest environmental degradation are warranted.

Our main contribution to the emerging literature on energy security for the region is two-fold: first, we articulate the need for achieving energy efficiency for achieving energy security for the region. In so doing, we examine the question of energy efficiency for the regional economies of the ACI counties. Our second contribution is to understand the factors that promote and factors that inhibit energy efficiency in the region. From the baseline model we are able to explore the rationale for policy coordination for the ACI countries for ensuring energy security in the region. The plan of the paper is as follows: in Section 2 we examine the role of energy efficiency. Section 3 we introduce an index of energy efficiency for measuring energy efficiency for the region. In Section 4 we investigate the relevance of policy coordination for the ACI countries in the light of the index of energy efficiency.

2. Relevance of Energy Efficiency: An Overall Picture

Energy efficiency and conservation are the major means in fighting adverse consequences from climate change and softening the impacts of environmental implications of the energy sector. Energy efficiency is also central to a society in reducing its external dependency and vulnerabilities from the energy domain. Energy efficiency is conceived as the improvement (increase) in the efficiency with which energy is used to provide a certain product, or service. Energy efficiency is hence measured in units of output per energy unit. Benefits of energy efficiency are multiple: first, it allows us to conserve on our scarce economic resources, secondly, it lowers the pressure on our limited fossil resources (on which our current energy supply mostly depends) and, finally, is usually regarded as one of the better alternatives for reducing carbon dioxide (CO_2) emissions.

The key for the existence of all these benefits relies on the fact that people have derived demand for energy as they do not consume energy *per se* and, instead, seek to use energy services. Therefore, it is often feasible to provide the same level of energy service with a lower consumption of energy, which forms the core of energy efficiency. The statistical relationship between energy efficiency and carbon emissions has been highlighted in the work of Schipper *et al* (1997), Ang (1999), Roca and Alcántara (2001) or Zhou and Ang (2008) among others. This relationship depicts energy efficiency as the alternative with the largest potential and cost-effectiveness to mitigate CO_2 emissions. The Intergovernmental Panel on Climate Change, in its Fourth Assessment Report (IPCC, 2007), estimates that 7–14% of the global greenhouse gas (GHG) emissions might be saved with negative cost measures, most of which will materialise from energy efficiency triggered by increasing energy prices. The International Energy Agency (IEA, 2008) also regards energy efficiency should provide 43% of the emissions reduction envisaged in their BLUE scenario (which sets the objective of reducing GHG emissions by 50% for 2050). Within the European Union energy efficiency is a major instrument in the climate action program[7]. The European Union has expressed its commitment to energy efficiency by "doing more with less" (EC, 2005). The European Union also seeks to devise a European strategy for a maintaining a reliable, competitive and sustainable energy supply (EC, 2006a). In many proposals related to what is known as the Climate Action Program energy efficiency plays a pivotal role with regards to the EU objectives on climate change (EC, 2008)[8].

The so-called energy efficiency paradox (or energy efficiency gap) is the observation that, although energy efficiency seem to accord economic and environmental advantages, the level of investment in them fail to be inadequate[9]. In an important study McKinsey (2007) estimates a potential for reducing energy demand growth by 50% in the next 15 years at competitive costs. The low-cost potential is propelled by investment in energy efficient technologies. Yet there is ample evidence that economic agents do not adequately invest in efficiency and conservation. There are two extreme positions for explaining the rationale for underinvestment in energy efficiency: on the one hand, we note authors argue that energy markets are rife with failures that drive underinvestment in energy efficiency. On the other hand, authors stress that there is neither an over or under investment once one takes consumer rationality into account[10].

Most of the earlier studies of industrial energy demand followed the seminal work of Berndt and Wood (1975) and concentrated on factor substitution and subsequently inter-fuel substitution models. However, these models were based on a 'strict' neoclassical production and cost structure (normally represented by the translog function) that were often at odds with the data and, as Waverman (1992) states, the results from such models were "based mainly on intuition and thus incorrect" (p. 23). More recently, a number of studies of industrial energy demand published since 1990 have continued to employ

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[7]However, attempts at energy efficiency are often considered ineffective as energy demand seems to grow unbridled in most countries. However, it is also recognised that that energy intensity (energy units per unit of GDP) has decreased in many countries. This decrease, sometimes rationalized on the basis of the "dematerialization" of the economies of these countries (e.g., Medlock, 2004), has put a brake on growth of energy demand despite continuing GDP growth.

[8]Richmond and Kaufmann (2006) highlight that the rising energy price explains the evolution of energy intensity in most countries, so that the dematerialization hypothesis should be rejected when prices are considered. The role of energy prices, which partly promotes greater efficiency of processes and structural shifts, is supported by the work of Metcalf (2008). On the other hand, Sue Wing (2008) argued that energy efficiency is not the major force behind energy intensity, or absorption, as the structural shifts in the economy are the sources of declining energy intensity, or absorption.

[9]The major benefits of energy efficiency, as usually cited, would be the decrease in the amount of energy resources needed to provide a certain level of energy service, with the corresponding implications on resource depletion, energy security, and monetary savings; and the reduction in carbon emissions, other pollutant emissions, and in general terms, the environmentalism pact related to energy use.

[10]There is a strong belief that investments that actually take place are economically optimal, given that energy markets are efficient. Therefore, if there is less investment than expected in energy efficiency, this is due to decisions based on the economic rationality undertaken by relevant economic decision-makers. In this sense, the divergence with the estimated technological potentials would be mostly explained by not accounting for the consumer behaviour (Metcalf and Hassett,1999; Huntington et al, 1994). It is also argued that technological potential studies underestimate costs and overestimate benefits because they have been generally carried out by biased institutions or agents (Joskow, 1994).

factor substitution models but in addition a number of studies have used a single equation approach often with a constant elasticity of demand (linear in logs) function. This procedure has become standard in energy demand estimation given its simplicity, straight forward interpretation, and limited data requirements and, as noted by Pesaran et al. (1998), it generally outperforms more complex specifications across a large variety of settings.

2.1 Relevance of Energy Efficiency for the Region

Energy efficiency and conservation are the major tools in the reduction of environmental impact and ecological footprints of the energy sector, particularly with regard to climate change. Energy efficiency also contributes to reducing external dependence and vulnerabilities of nations to shocks in the energy domain. At the global level, for arresting the global environmental degradation and costs of climate change, energy efficiency is of utmost importance for the emerging economies of Asia as the centre of gravity of the global economy has been continually tilting towards the Northern Indian Ocean close to the geographic proximity of ASEAN-China-India known as ACI nations. With a combined population of 3.15 billion and intraregional annual trade amounting to $1 trillion, the ACI nations are and will remain a major user of energy. ACI nations will be an important piece in the jigsaw puzzle of the sustainability of the global economy. In other words, ACI nations will pose a serious risk for creating and exaggerating the vulnerabilities of the global economy to shocks in climate change. In this paper we develop a quantitative technique, for the very first time to our best understanding, to examine the impacts of macroeconomic factors on energy efficiency and apply the method to understand the determinants of energy efficiency in ACI nations. The cross-country dataset is constructed on the basis of secondary data on energy uses and several macroeconomic variables for China, India and nine (9) ASEAN countries over the period of 1989–2010. From the empirical findings we highlight the most appropriate policies for improving energy efficiency in the region that will be the home of one half of the global population by 2030. Although not all public policies seem justified, we constructively demonstrate that specific policies for promoting energy efficiency may be required, preferably based on economic instruments.

3. Energy Efficiency Investment: A New Model of Reputational Equilibrium with Interest Group Politics

The political power, or government, plays a crucial role in determining investment in energy efficiency and its allocation. If the political power is rational, it is going to use its energy efficiency investment to influence its reputation as an instrument for achieving certain political ends.

Since the government has power to determine energy efficiency with diverse impacts on the economy, interest groups will easily form and use “pressure tactics” to wrench benefits from energy efficiency investment. If an interest group tries to influence the government for specific targets in energy efficiency investment, we label the behaviour as “*Wrench*”. If an interest group decides not to influence the efficiency policy, we label the decision as "*Waver*". We assume that there are multiple interest groups in an economy who compete against each other to influence energy efficiency investment. For our analysis, we posit that there are two social groups who form the rival interest groups: first, we have the pro-energy-efficiency interest group (RIG) and secondly, we have the anti-energy-efficiency interest group (UIG). In the usual parlance some may like to read the RIG as the environmental lobby group and UIG is the industrial lobby group. As our empirical section will confirm that a bipartite division of interests groups is a reasonable abstraction for the problem on hand.

We posit that the political power, or government, faces these two interest groups in two separate arenas: let us call Arena I where the RIG seeks to influence the political power to achieve its ideal mix and level of energy efficiency investment. In a similar note, Arena 2 is the contest ground for the UIG and the political power. The political power has two options: i) either it chooses to accommodate the political pressure from the interest group, which we call "Relent", ii) or the political power chooses an aggressive response, which we call "Resist". There are two types of political power and the political power only knows its true type: political power is either "Weak" or "Strong". So, the incumbent government, after elections have taken place, can either be a "Strong Government" or "Weak Government". The payoffs will determine the nature of government in our analysis. The payoffs to the players are as follows:

Table 1: Payoffs to the Agents in the Arena I

RIG's & Government's Choices	Payoff to RIG	Payoff to Strong Government	Payoff to Weak Government
Waver	0	A	A
Wrench and Resist	–1	0	–1
Wrench and Relent	B	–1	0
Reputation (R_1)		R_1	$1 - R_1$

Source: constructed by the authors.

The government is modelled as either "Strong" or "Weak". It is Strong if it can resist pressure tactics from the RIG. It is Weak if the government is expected to succumb to the pressure from the RIG in Arena I. The payoff structure is explained by the nature of the contest:

- If RIG wavers it gets nothing and the government is free to pursue its energy policy and the payoff to either type of government is 'a'.
- If RIG decides to wrench and the government resists, then the RIG makes a loss (–1). The payoff to a strong government (0) is greater than the payoff to a weak government (–1).
- If RIG decides to wrench and the government chooses to relent, the interest group gets b, its maximum return. The strong government loses its face more than a weak government by capitulating, so the payoff to a strong government (–1) is less than the payoff to a weak government (0).

- R_1 is the probability assessment by the RIG about the type of the government being "Weak". So $(1 - R_1)$ is the subjective probability assessment that the government is "Strong".

The contest game gets played in the second arena (Arena II) between the government and the UIG. We present the details of the contest game in Table 2:

Table 2: Payoffs to the Agents in the Arena 2

UIG's & Government's Choices	Payoff to UIG	Payoff to Strong Government	Payoff to Weak Government
Waver	0	H	h
Wrench and Resist	–1	0	–1
Wrench and Relent	j	–1	0
Reputation (r_1)		r_1	$1 - r_1$

Source: Constructed by the authors.

The structure of the payoff in Table 1.2 is exactly the similar except the values (h, j) and the probability assessment (r_1). Once can linearly read Table 1.2 from the explanation of Table 1.1.

Observation 1: When $R_1 = 0$ and $r_1 = 1$, the government is known to be immune from the pressure tactic in Arena II. However, it is reputation is low in Arena I and the government is expected to capitulate to the pressure from the RIG. Consequently, the energy-saving policy will be influenced by the preferences of the RIG.

Observation 2: When $R_1 = 1$ and $r_1 = 0$, the government is known to be immune from the pressure tactic in Arena I. However, it is reputation is too low in Arena II and the government is expected to capitulate to the pressure from the UIG. Consequently, the energy policy will be influenced by the preferences of the UIG.

Observation 3: Consider the case where $R_1 < \frac{b}{1+b}$ (1a)

A minor manipulation will yield:

$$-R_1 + (1 - R_1)b > 0 \tag{1b}$$

The left hand gives the expected payoff to the RIG from wrenching. Since by construction the payoff to the RIG from wavering is zero (0), hence (1b) gives us the condition that the expected payoff from "Wrench" is greater than that to from "Waver". Therefore in Arena I the RIG will seek to influence the energy policy and spending.

Observation 4: Consider the case where $r_1 > \frac{j}{1+j}$ (1c)

In this case the gain from wrenching in Arena II by the UIG is greater than the gains from wavering. Hence the UIG will put pressure to shape the energy policy close to its own preferences.

Observation 5: Assuming $R_1 = r_1$, such that both groups share their probability assessment about the government, consider the possibility where

$$r_1 = R_1 < \frac{j}{1+j} < \frac{b}{1+b} \tag{1d}$$

Both these interest groups have incentives to challenge the government in order to influence the energy policy, or spending on alternative sources of energy. Such attempts can lead to political crises, or at least the government will choose a compromised policy as a combination of the ideal preferences of the two interest groups.

Observation 6: If the reputation is such that

$$\frac{j}{1+j} < r_1 = R_1 > \frac{b}{1+b} \tag{1e}$$

Then neither interest group has incentives to challenge the energy efficiency investment. The government will be free to pursue an independent energy policy – independent of the interest groups. The value of its reputation is such that neither interest group wants to test out the government in the contest. This is an interesting - some may call it stunning - result from ambiguity: neither interest group believes that the political power is truly strong, yet the political power stays immune from challenges to deliver the energy policy of its choice. In other words, the government is not strong, yet it enjoys some room to manoeuvre in deciding the energy efficiency investment and its allocation. The government has the limited autonomy to undertake its energy policy without challenges from powerful interest groups.

All these observations are true for single-shot games. The main frame of interactions is ideally captured by a finitely repeated game (say, at the end of the term of a government). If the game is finitely repeated, the logic of backward induction will not make any material change from the outcomes considered in the one-shot versions as above.

If the games are repeated without a known finite end date, then the government has an incentive to influence the subjective estimates about its type so that the government can have a free rein in the determination of energy efficiency investment or its allocation. More importantly, if the true type of the government is not known a priori, then the government will have to teach the "foolish challenger" that the government is strong – but this is costly for all. So, for the conditions given by (1a)-(1f), the government will disclose its true type and be influenced by either or both interest groups. But if condition (1e) holds, and if there is not a clear end date for the game, the government will engage in reputation building over time to stall any interest group pressures. This is what we summarise in the first result:

Result 1: By exploiting the logic of mixed strategy equilibrium, the reputational dynamics, or path, of the political power is given by equation (1f) such that there is no incentive for RIG to influence the energy policy where t represents time:

$$\frac{dR1}{dt} = (1+bt)^t \tag{1f}$$

Result 2: By exploiting the logic of mixed strategy equilibrium, the reputational dynamics, or path, of the political power in Arena II is given by equation (1g) such that there is no incentive for UIG to influence the energy policy where t is the time:

$$\frac{dr1}{dt} = \left(1 + jt\right)^{t} \tag{1g}$$

In summary it is shown that the 'bad or fuzzy' information about the type of the government and its relationships with potential interest groups can pay the political power to pursue the optimal energy policy from its point of view. However, this is feasible only for a short-time and also along the above paths that give the updating of subjective beliefs of interest groups. Otherwise, the political power will succumb to pressure group politics in its pursuits of energy policy. If the interest groups want to seek the strength of the political power, it prefers a challenge in the arena where the government is strong.

Result 3: If the UIG and RIG are unsure about the true type of the government and expect the arrival of information concerning the true nature of the government from its actual energy efficiency investment, then the interest groups will have an optimal waiting time before challenging the government due to an option value from waiting (see Gangopadhyay and Gangopadhyay, 2008). During this waiting time, the government is free to choose the energypolicy but will be subject to heavy pressure from interest groups once the waiting period is over.

So, there may be temporary lull when energy efficiency investment is not subject to interest group pressures, but most often than not there will be pressure from interests groups on the political power to choose the energy policy to the benefits of the interest groups. However, which group wins to influence the political power is an empirical question that we will address in the next section.

4. An Index of Energy Efficiency for the ACI Economies by Using Stochastic Frontier Estimates

The existing work on energy models build on Gately and Huntington (2002), Griffin and Schulman (2005) at the national level to explain the energy consumption. We estimate a new form of energy efficiency equations for ACI nations during 1989–2010. To label the energy absorption, or consumption, by a country we use two indicators: first, we use the electric power use per capita (kWh per capita) in a country and label it as *EL* ignoring the time subscript. Secondly, we also use the per capita energy absorption/use measured by kg of oil equivalent per capita (*PCE*). We use a set of determinants of the use of energy and treat them as independent variables and label the regressors as a vector R_i. The vector of regressors includes the following variables:

- POP_i: Population of country i
- GDP_i: National Income of Country i at 1989 prices
- $GDPA_i$: GDP generated by Agriculture
- $GDPI_i$: GDP Generated by Industry
- $FOODP_i$: Average Food Prices Prevailing in Country i

- $POPD_i$: Population Density of Country i
- $POPG_i$: Annual Population Growth in Country i
- $GROW_i$: Economic Growth of Country i.

We posit that a country's absorption, and production, of energy is given by:

$$Ln\ EL_i = \beta * R_i + e_i \tag{2a}$$

Equation (2a) is the energy absorption equation and $e_i$is a stochastic error term that is normally distributed $N(0, \sigma^2)$. In the frictionless world, the government of a country has the perfect information about energy-saving technologies and is free to adopt them instantly to achieve the target absorption of energy, T_i , instantly, which implies a costless and perfect matching of production and energy use in Country i. In an imperfect world, with incomplete information and lack of perfect control over energy-saving projects and lobbying by interest/pressure groups -each nation will adopt/accept sub-optimal energy-saving regime W_i^O. Note both T_i and W_i^O are expressed in $Ln\ EL_i$, $T_i$is not observed but calculated while

W_i^O is the observed energy absorption. We posit that

$$W_i^O - T_i = U_i \tag{2b}$$

Note that $U_i \geq 0$ and is an index of relative inefficiency in choosing energy-saving projects and from (2a) and (2b) we get:

$$W_i^O - \beta^* R_i + v_i \tag{2c}$$

$$v_i = e_i - U_i \tag{2d}$$

From the mean and mode of (e_i/v_i) for each country i, following Polachek and Robst (1998), one can calculate an index of relative inefficiency of each country to adopt energy-saving measures. Estimates of energy inefficiencies are calculated by computing the excess of actual energy use over the target/potential energy use of each country. The target energy use is computed from the stochastic frontier analysis. The approach is similar to the Aigner, Lovell, and Schmidt (1977) model except the stochastic frontier and inefficiency effects are modelled as a function of individual specific factors in a one-step procedure. We model the relative inefficiency of Country i as a function of the independent and macroeconomic variables.

3.1. The Postulated Model of Estimation

In what follows we represent the stochastic part of the frontier by the variable v that has a zero mean and a variance σ_v^2. We postulate σ_v^2 to be constant. The inefficiency of a country to reach the frontier (optimum) is measured by U_i with a mean zero and variance σ_u^2. We posit that the variance in inefficiency is influenced by economic factors as expressed in equation (3a). We fit the following model to derive the index of energy inefficiency for each country i in the ACI:

$$Ln\ EL_i = W_i^O = \beta_0 + \beta_1 Ln\ POP_i + \beta_2 Ln\ GDP_i \tag{2a}$$

Subject to

$$Ln\, \sigma_u^2 = F(POPD_i, POPG_i, GROW_i, FOODP_i, \text{Constant}) \tag{3a}$$

$$Ln\ \sigma_v^2 = f\,(\text{Constant}) \tag{3b}$$

Note that we have used various versions of (3a) and (3b) and summarise a few of the statistical results in sub-section 3.2.

3.2 Results from Stochastic Frontier Analysis

The stochastic frontier results are summarised in Table 1 and some interesting observations are given here, further details can be obtained from the corresponding author:
As expected that the size of population puts serious pressures on ecological footprints as the coefficient is economically significant (0.87) and statistically significant. Thus, the main threat to ecological sustainability to the region arises due to the population pressure though the elasticity is less than one but close to the value of one (1).

- As expected the increase in the size of GDP does not increase the ecological footprints since economic development allows nations to invest more in eco-friendly and alternative technologies. However, the coefficient is not statistically significant. A more detailed analysis is warranted in future work.
- The food price index, as an indicator of wage cost (cost of production), has little impact on the efficiency index – though the coefficient is positive but small and not statistically insignificant.
- It is important to note that the population density (*POPD*) improves energy efficiency. The possible link is through two mechanisms: (i) as more people come to share a small economic space, the per capita consumption of electricity will decline due to lower per capita space. (ii) secondly, the fast pace of urbanisation in the region makes people more aware of environmental consequences of over consumption of energy, which lowers the absorption of the electrical energy by each person with an increased pace of urbanisation.
- In a similar vein, the faster economic growth in the region leads to a substitution of electrical energy by other forms of energy both in the production and consumption bundles. Thus, an increase in growth (*GROW*) causes an improvement in the energy efficiency in the region.
- However, population growth (*POPG*) lowers the energy efficiency in the region.

Table 1: Electricity Consumption and Determinants of Energy Efficiency

Dependent Variable: *Ln EL*

Regressors	Coefficients	Standard error	p-values
Ln POP	0.88***	0.06	0.000
Ln GDP	–0.02	0.04	0.490
Constant	8.02***	0.59	0.000
Ln σ_v^2 (constant)	–0.35	0.34	0.320

Regressors	Coefficients	Standard error	p-values
Ln σ_u*2-*			
FOODP	0.001	0.001	0.440
POPD	–0.008**	0.003	0.013
POPG	0.52***	0.14	0.000
GROW	–0.14	0.04	0.000
Constant	1.33**	0.46	0.004

Note: Constructed by the author by using the frontier normal-half-normal model in Stata, Number of observations: 241, Wald chi^2 (2): 261.33, Prob > chi^2 = 0.000, Log likelihood = –406.50. The null hypothesis that there exists no technical efficiency coefficient is rejected, so the frontier results are robust. ***: Significant at 1%, **: Significant at 5%.

To check for further robustness we choose *LnPCE* as the dependent variable and retain the same analytical structure. Note that *PCE* is the per capita energy use measured by the kilograms of oil equivalent per capita. The results are presented in Table 2 and are in conformity with our overall findings. The key difference between Table 1 and Table 2 is the impact of GDP on the dependent variable: in Table 1 we find the elasticity is negative and statistically insignificant. This is expected as GDP rises nations move out of electricity consumption to alternative sources of energy. In Table 2 we find the per capita energy consumption has a positive elasticity with regards to the GDP variable. The coefficient is also statistically significant. This is also expected since the per capita energy consumption rises with rising GDP though nations substitute away from electricity to other sources of energy.

Table 2: Per Capita Consumption of Energy and Energy Efficiency

Dependent Variable: *Ln PCE*

Regressors	Coefficients	Standard error	p-values
Ln POP	0.50***	0.010	0.000
Ln GDP	0.035***	0.007	0.000
Constant	9.49***	0.00005	0.000
Ln σ_v^2 (constant)	–33	193.3	0.832
Ln σ_u^2			
FOODP	0.001**	0.0007	0.024
POPD	–0.11***	–0.107	0.000
POPG	0.13	0.13	0.260
GROW	0.088***	0.08	0.000
Constant	2.42***	0.39	0.000

Note: Constructed by the author by using the frontier normal-half-normal model in Stata, Number of observations: 241, Wald chi^2 (2): 261.33, Prob > chi^2 = 0.000, Log likelihood = –406.50. The null hypothesis that there exists no technical efficiency coefficient is rejected, so the frontier results are robust. ***: Significant at 1%, **: Significant at 5%.

4. Policy Coordination for Sustainable Economic Progress in the Region

The major source of pollution in the region is the older models of production of electrical energy by burning coals for both production and consumption. The other major source is the burning of fossil fuels (oil) for automobiles. There are several crucial observations in order:

- First, the ACI nations need coordination of demographic and migration policies. It is important to note that the absorption of electricity from polluting (coal-fired) stations bears a positive relation with the population size in the region. In order to reduce adverse ecological consequences, it is important to control both the size and the growth of population.
- Secondly, urban centres with high population densities promote energy efficiency, the migration policy of the ACI countries should be coordinated to create urban centres with migrant stocks from different nations.
- Thirdly, economic growth seems to promote energy efficiency and coordination of foreign direct investment to the region can help overcome the adverse effects of economic shocks.
- Finally, economic development in the region lowers the appetite for polluting energy sources. Policy coordination to tackle adverse economic shocks, by monetary and fiscal policy synchronisation, is also an important means to achieve energy efficiency in the region.

5. Conclusion

By using the stochastic frontier analysis, we are able to understand how coordination of various policies in the ACI economies can improve energy efficiency in the region and promotes the sustainability of the centre of gravity of the global economy. We note the collective importance of demographic and migration policies along with urbanisation and an appropriate mix of fiscal and monetary policies, which can reduce the adverse environmental impacts from the uses of older and polluting technologies of producing electricity in the coal-fired plants producing electricity in the ACI economies.

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